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Effect of delay in layering on the incremental adhesion of indirect dental composite resins

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ABSTRACT

Adhesion of the new layer of indirect composite resin (ICR) to the already polymerized one may be affected when the time between the applications of subsequent layers is prolonged. The aim of this study was to compare the shear bond strength and degree of conversion (DC) of two ICR systems with different compositions and adhesive promoters, relayered after four time points. Disk shaped ICR materials (ICR1 = Sinfony and ICR2 = Targis) ($N=96$, $n=48$ per material) were fabricated and processed according to each manufacturer's instructions. They were then randomly assigned to 4 groups. While immediate layering acted as the control group, after 5 min, 24 h and 1-week delay, a new layer of the ICR of the same kind with the substrate was adhered to the substrate in polyethylene molds. The bonded specimens were loaded under shear (1 mm/min) and bond strength was calculated. DC of ICR1 and ICR2 were similar (75 ± 1, 75 ± 2, respectively). Delay in relayering at different timepoints did not significantly affect the adhesion between the incremental layers of ICR1 (32–34 MPa) compared to the control group (34 MPa), but the adhesion between the layers of ICR2 showed decreased bond strength after 24 h (30.9) and especially more after 1 week (25 MPa) compared to immediate layering (38.9 MPa). The effects of ageing before bonding additional layers of ICRs is variable, and depends on the chemical formulation of the ICR as reflected in the different brands.

1. Introduction

Dental composite resins are types of synthetic resins that are used in dentistry as restorative materials or adhesives [1]. Similar to other composite materials, a dental composite resin typically consists of a resin-based oligomer matrix usually based on bisphenol A-glycidyl methacrylate (bis-GMA) or urethane dimethacrylate (UDMA) consisting silanized inorganic fillers such as silicon dioxide (silica), barium, quartz or zirconia [2,3]. In today's dentistry, composite resins, applied directly by the clinician or fabricated indirectly in a dental laboratory and cemented in vivo, occupy a paramount position and present acceptable clinical performance with much lower costs than their ceramic counterparts [4,5]. Indirect composite resins (ICRs) were introduced in the dental market in an effort to address the disadvantages of the direct adhesive restorative materials such as technique sensitivity, difficult establishment of superior anatomical form, polymerization shrinkage or wear [6,7]. ICRs are polymerized outside the mouth, in polymerization units that are capable of delivering higher intensities and levels of energy for polymerization compared to those of hand-held polymerization units. Indirect fabrication of composite resin restorations in a laboratory or chairside on a plaster model, subsequently adhesively cemented, provide improved quality of interproximal tooth contact, that is the contact between restorative material and the adjacent tooth, compared to direct application of such restorations [4]. ICR materials provide alternative ways for clinicians to overcome some inherent deficiencies of direct composite resin restorations, including polymerization shrinkage, their inadequate polymerization in deep interproximal areas between two neighboring teeth. Limited light transmission in such areas may yield to insufficient polymerization of the material [8–10].

Fixed dental prosthesis (FDP) is any dental prosthesis that is luted, screwed or mechanically attached or otherwise securely retained to natural teeth, tooth roots, and/or dental implant abutments that furnish the primary support for the dental prosthesis [11]. They can be metallic, ceramic or combination of both. ICRs are advantageous from optical point of view over metal-ceramic FDPs due the lack of metal in the reconstruction. Moreover, ICR FDPs show decreased wear of opposing dentition when compared to ceramic [6,7]. Also, finishing and polishing procedures are easy to perform and restorations can be repaired, if needed, using proper adhesive repair protocols [8,9,12,13].

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In order to overcome some of the deficiencies of the directly placed composite resins, attention has been directed to laboratory-processed composite resins. During the last two decades ICRs have gone through substantial changes in their process and compositions [7]. Ultra-small filler particles and polyfunctional methacrylate monomers are frequently used in ICRs [14,15]. Compared with direct composites, they are processed utilizing different laboratory techniques based on combinations of heat, pressure, vacuum and photo-polymerization. Indications of ICRs are inlays, onlays, veneers, single-unit and short-span anterior or posterior FDPs [7,9,10,12,13].

A variety of materials with remarkable differences in composition, polymerization modes and conditions comprise the second generation of the laboratory-processed ICRs [16–23]. Second generation ICRs became available in 1995 and their inherent characteristics and clinical performance have not been widely investigated [6,8,24,25]. Although the recently introduced systems claim improved clinical performance and optical properties, some studies noted delamination of the veneering ICR from the substructure that is attributed to layering techniques used during the fabrication process [5,26,27]. The reason for this could be associated with the inadequate adhesion during incremental build-up between the highly converted ICR layers [28]. In general, adhesion between two composite resin layers is achieved in the presence of an oxygen-inhibited layer of unpolymerized resin [29–31]. Yet, controversial opinions exist on the effect of oxygen-inhibited layer on the adhesion between two composite resin layers [32–35]. Considering the time needed for the completion of an ICR restoration that often ranges from some minutes to hours, changes in the oxygen-inhibited layer could affect the adhesion between the layers during build-up [36,37]. In some cases, especially after clinical trial, color adjustments may necessitate addition of new layers even after some days. Adhesion between two composite resin layers is achieved in the presence of an oxygen-inhibited layer of unpolymerized resin but radical half-life decreases by time [29–31]. Thus, it can be hypothesized that adhesion between ICR layers can be impaired when relayering is performed at delayed time points compared to immediate incremental layering. While manufacturers of some ICR systems recommend the use of silane coupling agent between the increments to increase the wettability of the subsequent increment, others suggest the use of methacrylate based adhesive resin to achieve interpenetrating polymer network to activate the substrate surface for co-polymerization [28].

The objectives of this study therefore were to evaluate (a) the degree of conversion and (b) the incremental bond strength of ICR substrate and adherend in two systems with different compositions and adhesive promoters, relayered after four time points.

2. Experimental

2.1. Materials and methods

The brands, main chemical compositions, corresponding polymerization modes, batch numbers, manufacturers, the shades of the ICRs and the conditioning materials used for the experiments are listed in Table 1.

Cylindrical cavities (diameter: 5 mm, height: 3 mm) prepared in auto-polymerized polymethylmethacrylate (Autoplast, Candulor AG, Wangen, Switzerland) surrounded by a PVC cylinder (3 specimens per cylinder) were filled with either flowable ($n=48$, 12 per group) (ICR1-Sinfony) or packable ICRs ($n=48$, 12 per goup) (ICR2-Targis). The unpolymerized composite resins were packed into the cavities with a hand instrument and photo-polymerized incrementally in layers of not more than 2 mm (Fig. 1a–d). Each increment was photo-polymerized initially with a halogen polymerization unit (Demetron LC, SDS Kerr, Orange, CA, USA) for 40 s from a constant distance of 2 mm from the surface. Light intensity (800 mW/cm^2) was verified by a radiometer (Demetron LC, SDS Kerr) after fabrication of every 12 specimen. The surface layer was flattened by translucent Mylar strip (KerrHawe SA, Bioggio, Switzerland) in order to create a smooth surface. ICR1 and ICR2 specimens were further subjected to oven polymerization. For ICR1 specimens, preliminary polymerization was achieved with Visio Alpha Unit (3M ESPE AG, Seefeld, Germany) (400 mW/cm^2, Programme 3, no vacuum) for 5 min. A second cycle of polymerization was performed for 15 min in the Visio Beta Vario Unit (3 M ESPE AG) (40 °C with vacuum, 470 mW/cm^2). For ICR2 specimens, preliminary polymerization was performed with Targis Quick Unit (Ivoclar Vivadent AG, Schaan, Liechtenstein) for 5 min (300 mW/cm^2). A second cycle of polymerization was made for

Table 1
Brands, main chemical compositions, corresponding polymerization modes, batch numbers, manufacturers, the shades of the ICRs and the conditioning materials used for the experiments.

Brand	Chemical composition	Polymerization mode	Batch number	Manufacturer	Shade
Sinfony	HEMA and 10–30 wt% octahydro-4,7-methano-1H-indenediyl bis(methylene)diacrylate, strontium–aluminum borosilicate glass, silicon oxide, silane and photoinitiators weight (%) organic fillers: 50%	First cycle: Polymerization for 5 min in the Visio Alpha unit (400 mW/cm^2, Programme 3, no vacuum) Second cycle: Polymerization for 15 min in the Visio Beta Vario unit (40 °C with vacuum, 470 mW/cm^2)	203216	3 M ESPE AG, Seefeld, Germany	A2
Targis	bis-GMA 20%, DDDMA,UDMA, TEGDMA Silanized barium glass fillers, photoinitiators, inhibitors and pigments weight (%) organic fillers: 46.2%	First cycle: Polymerization for 5 min in the Targis Quick unit. (300 mW/cm^2) Second cycle: Polymerization for 25 min in the Targis Power unit (68 °C with vacuum, 400 mW/cm^2)	15605	Ivoclar Vivadent AG, Schaan, Liechtenstein	A2
Targis wetting agent	3-methacryloxypropyltrimethoxysilane		815137	Ivoclar Vivadent	
Sinfony	activator	>90 wt% (octahydro-4,7-methano-1H-indenediyl)bis(methylene)diacrylate		034	3 M ESPE AG

bis-GMA=Bis-phenol-A-glycidylmethacrylate.
UDMA=Urethane dimethacrylate.
TEGMA=Triethyleneglycol methacrylate.
HEMA=2-hydroxyethyl methacrylate.
DDDMA=1,10-Decanediol dimethacrylate.